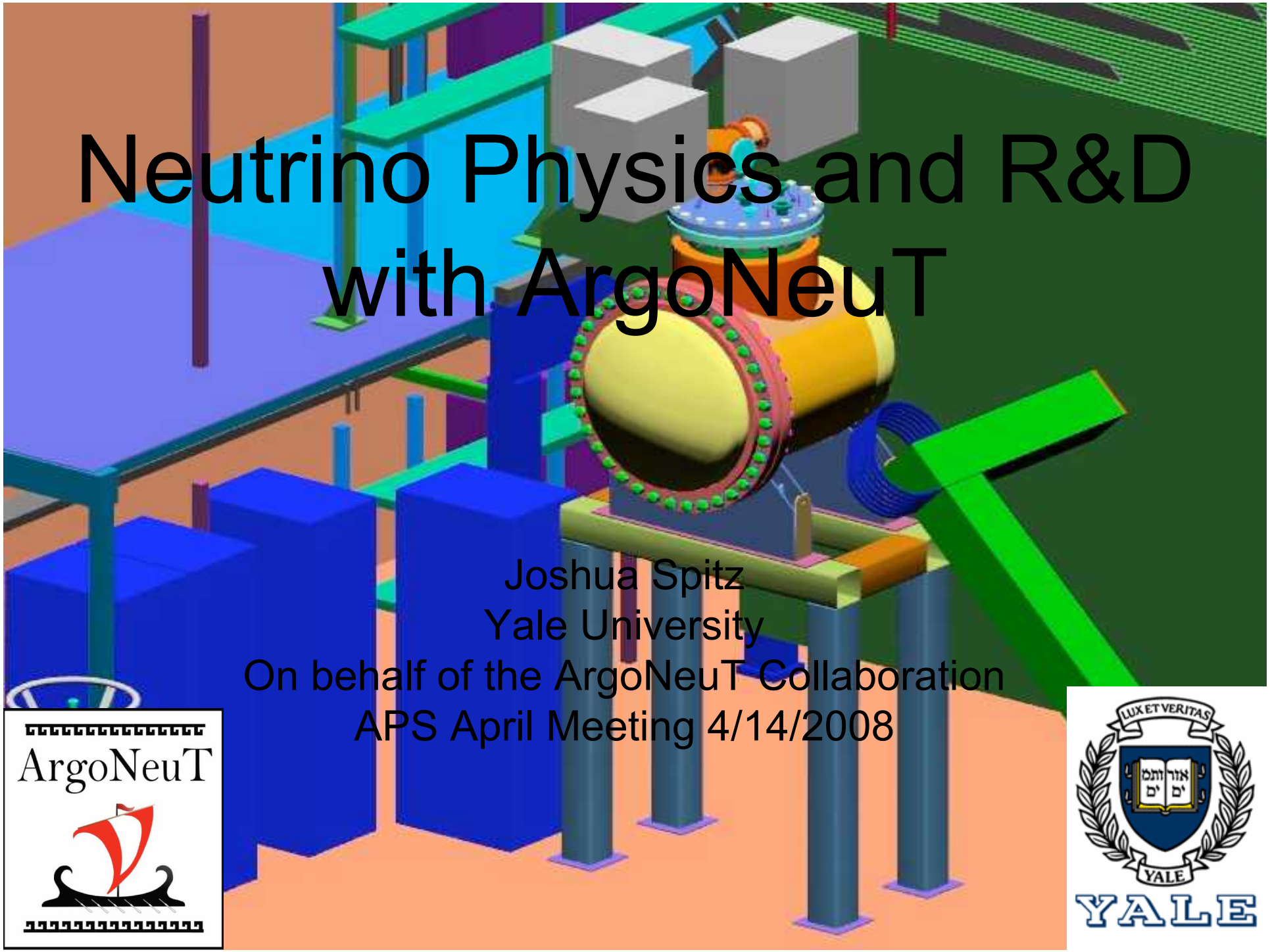
Neutrino Physics and R&D with ArgoNeuT



Joshua Spitz
Yale University
On behalf of the ArgoNeuT Collaboration
APS April Meeting 4/14/2008

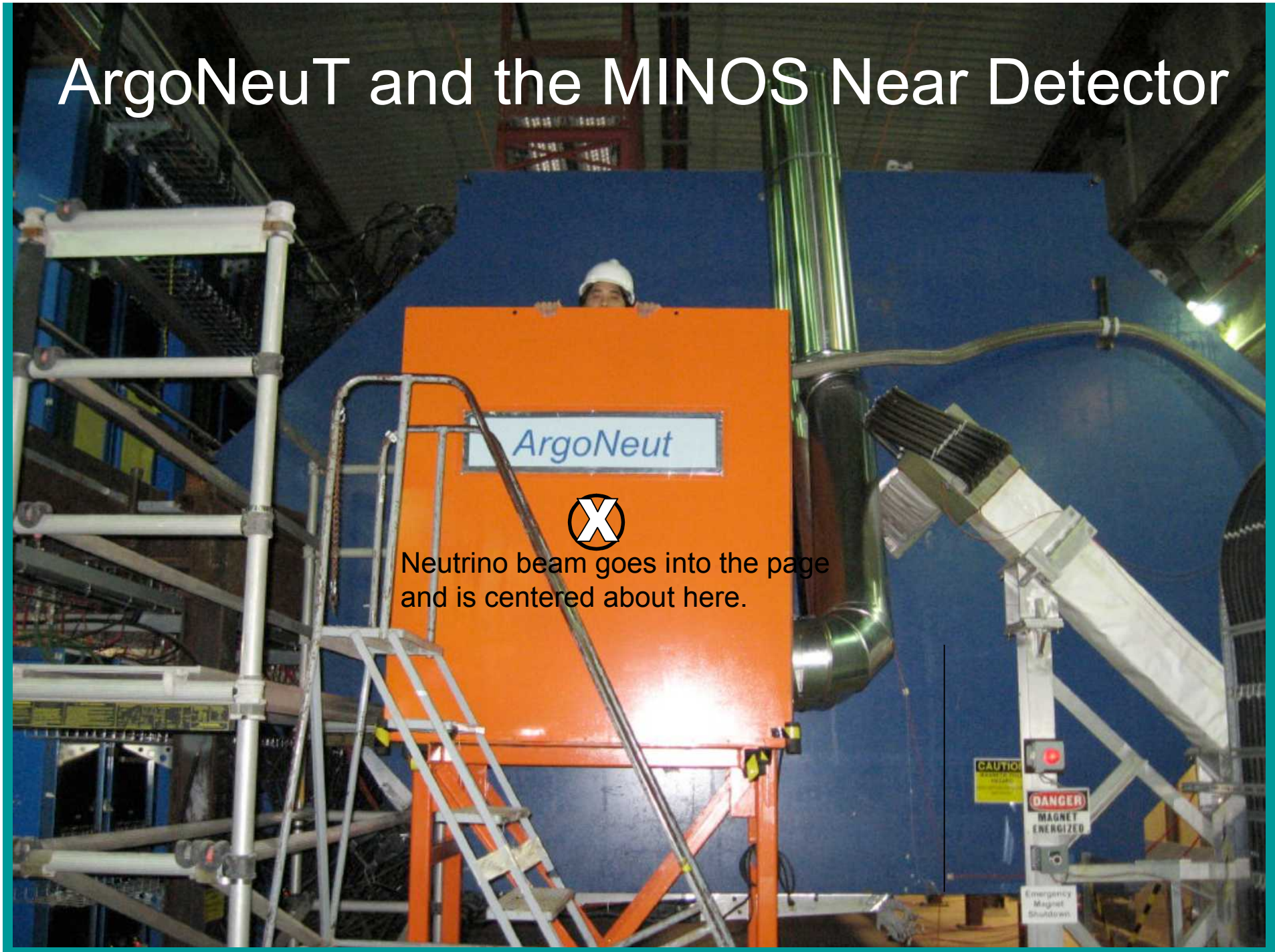
ArgoNeuT

YALE

Overview of the Experiment

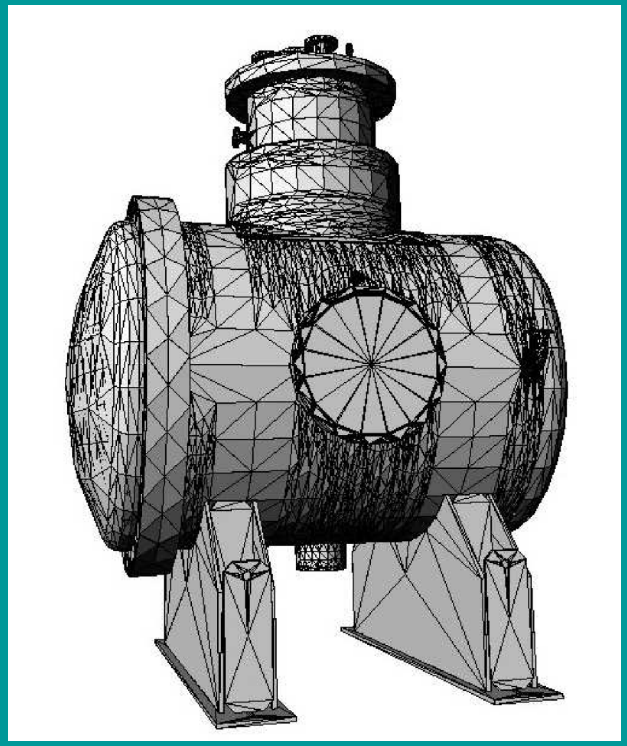
- ArgoNeuT is the first Liquid Argon TPC (LArTPC) to go in a “low energy” neutrino beam (NuMI on-axis, peaking at ~3GeV) . The first neutrino events are expected next month.
- We will see ~45000 neutrino events in the 170L TPC in ~180 days (Phase 1) of running.
- Goals:
  - Research and Design for future LArTPCs (MicroBooNE, long baseline neutrino oscillation, proton decay, …)
    - Argon purity, cold electronics, detector design and construction, etc.
    - Simulation and reconstruction framework
  - Demonstrate particle ID (e.g. electron/gamma separation) capabilities of LArTPCs with dE/dx
  - Physics?

ArgoNeuT and the MINOS Near Detector




RGON

ArgoNeuT Collaboration



F. Cavanna
University of L'Aquila

B. Baller, C. James, G. Rameika
Fermi National Accelerator Laboratory

M. Antonello, R. Dimaggio, O. Palamara
Gran Sasso National Laboratory

C. Bromberg, D. Edmunds, P. Laurens, B. Page
Michigan State University

F. Pietropaolo
University of Padova

S. Kopp, K. Lang
The University of Texas at Austin

C. Anderson, B. Fleming*, S. Linden, M. Soderberg, J. Spitz
Yale University

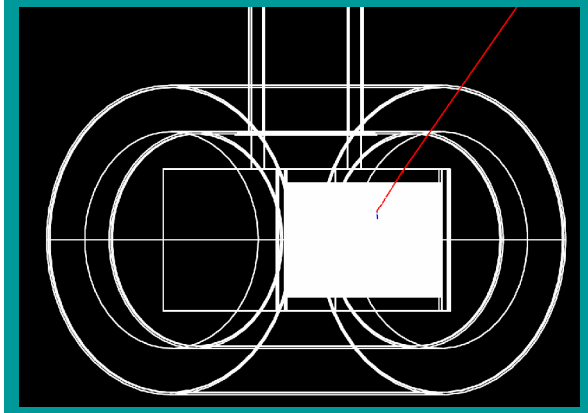
The Monte Carlo tree

gnumi near detector flux

CRY cosmic ray generator

GENIE neutrino generator (modified for LAr)

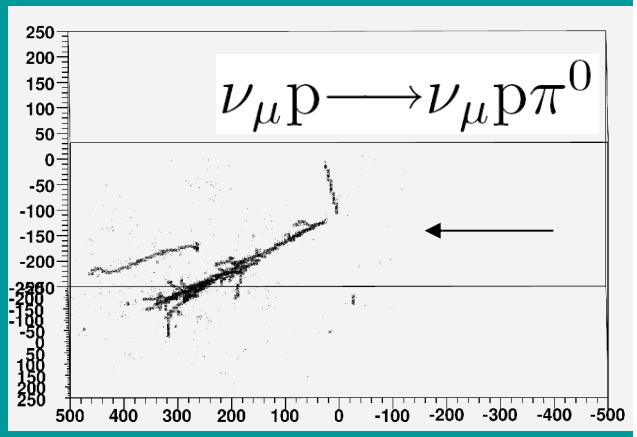
Nuance neutrino generator (modified for LAr)



Event initial conditions

e.g.

ArgoNeuT Geant4



Event

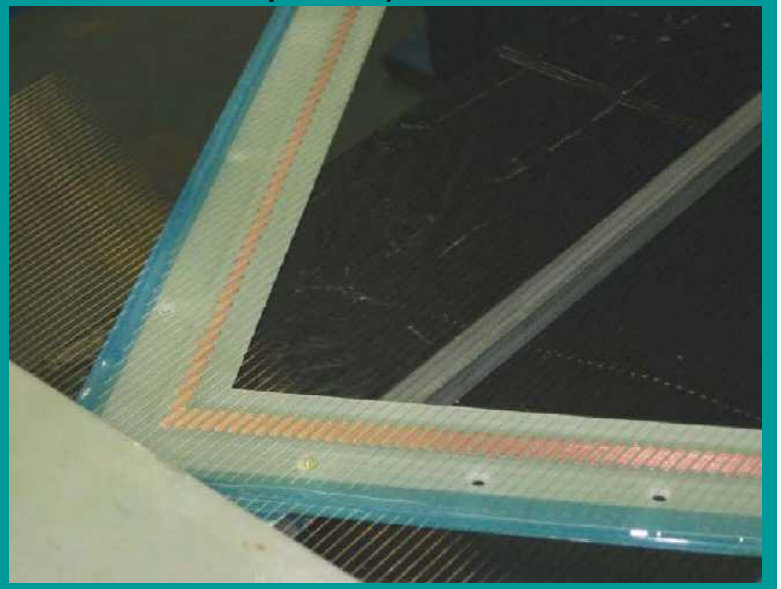
MC Steps
Interaction product info
Particle ID
Energy
Momentum vector
…

MC Truth
Initial neutrino info
Energy
Momentum vector
…

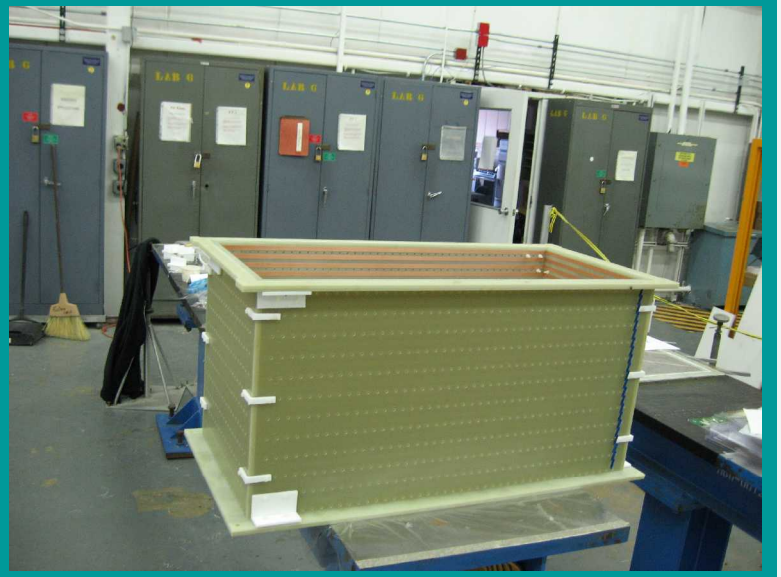
Hits->Digits->Wires
Wire # (position)
Charge (energy deposit)
Time

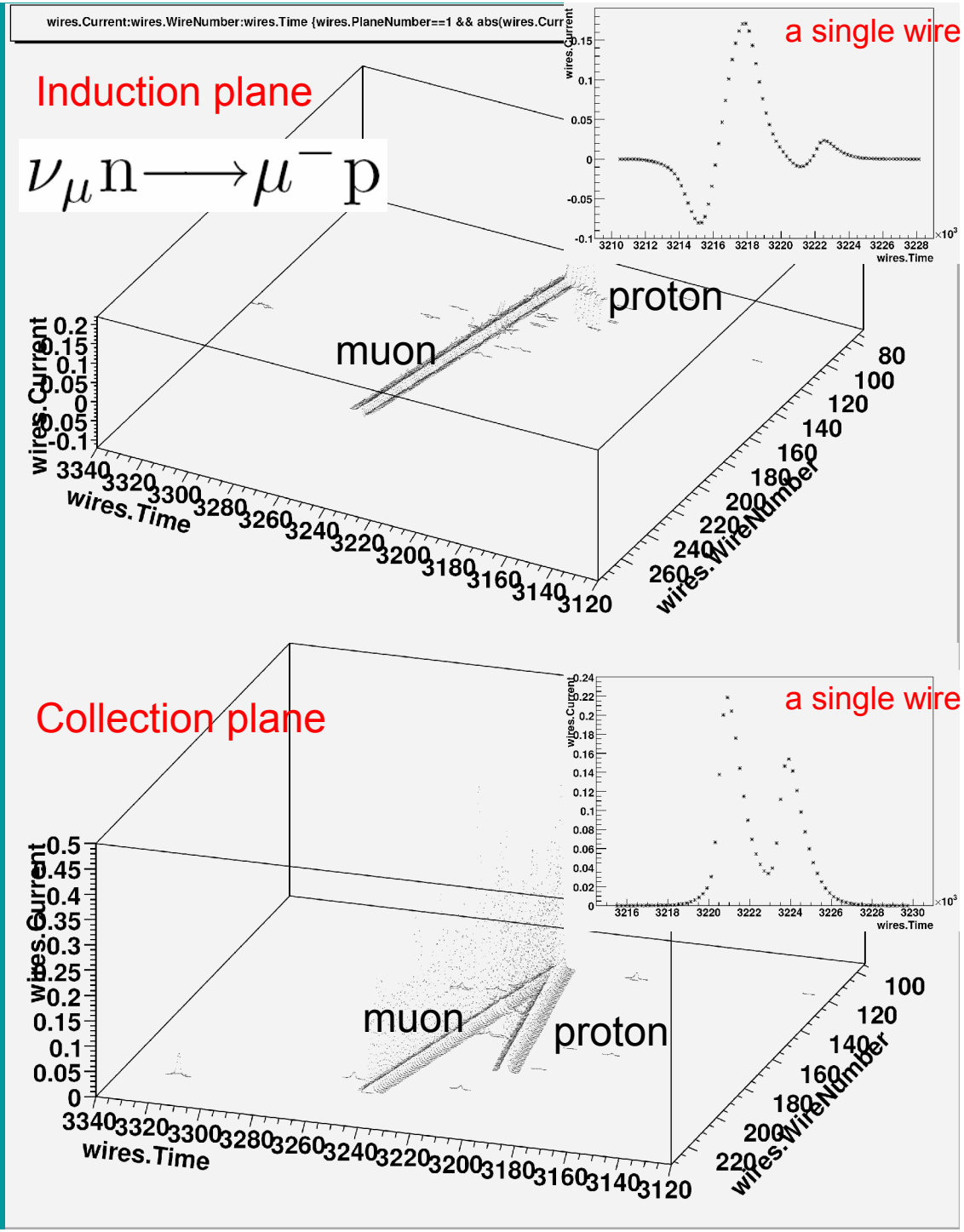
e.g.

4 mm wire spacing (260 channels/plane)



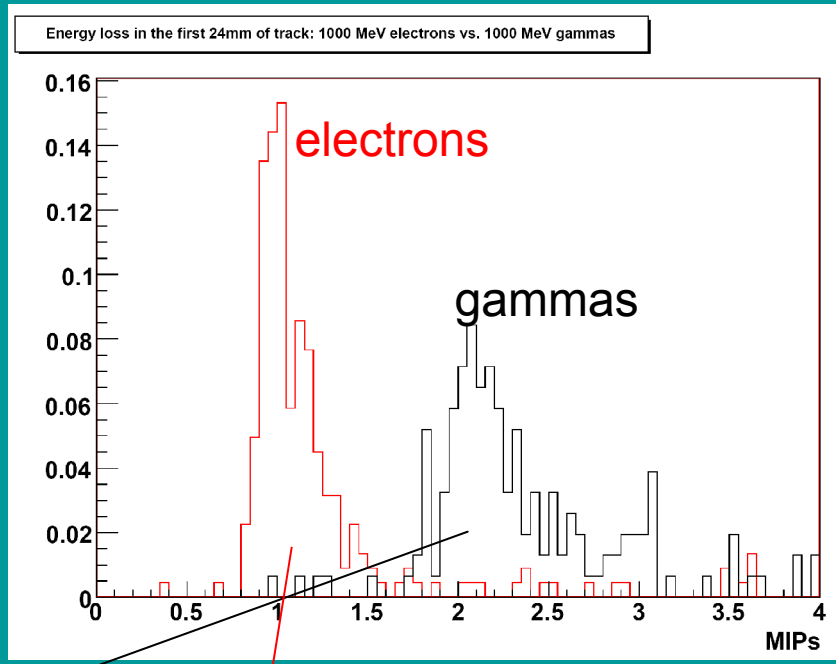
The TPC

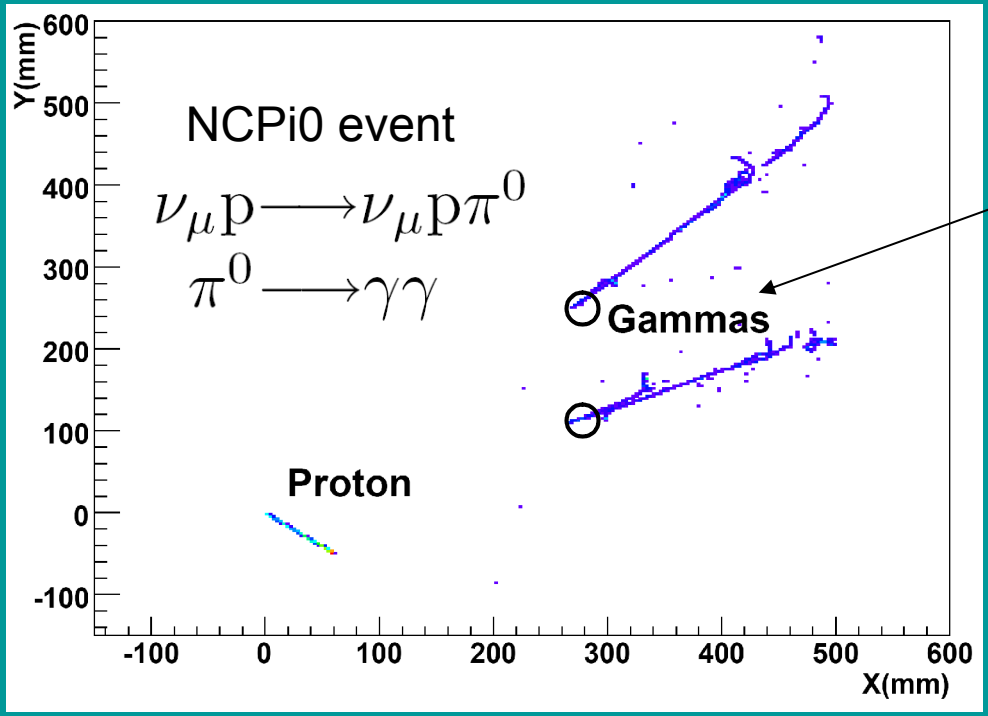


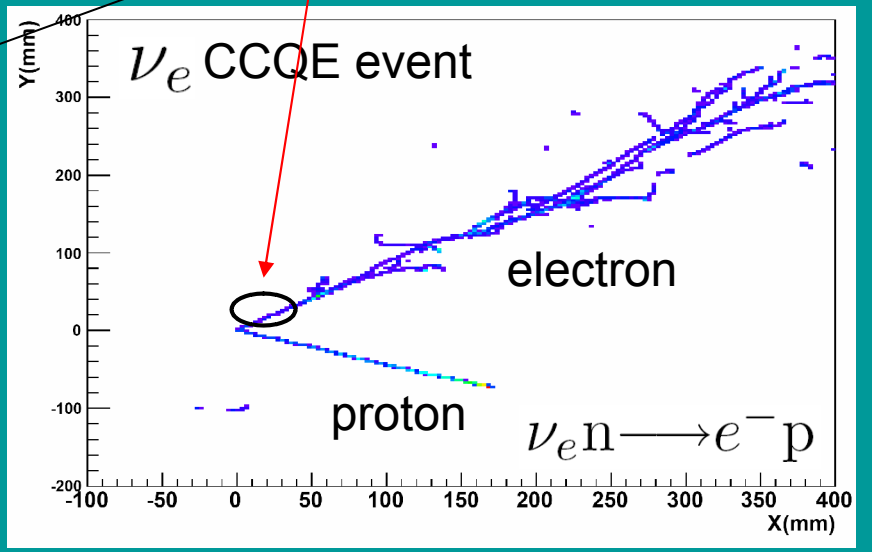


Particle tagging with dE/dx

- ArgoNeuT will demonstrate the LArTPC's ability to ID particles with dE/dx and topology.
- Monte Carlo studies indicate that LArTPCs can separate electron/gamma events with ~90% efficiency.







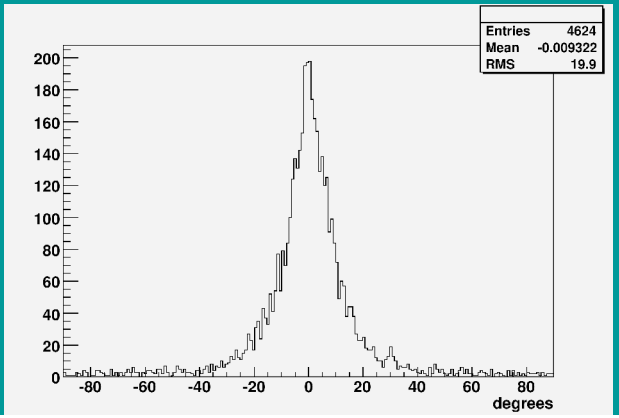
Event rates

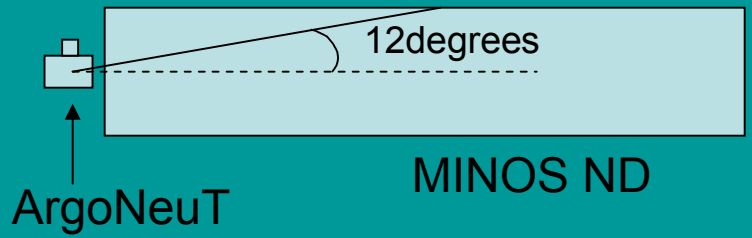
Phase 1

Note that ArgoNeuT will move in front of MINERvA for phase 2 and run for xxx days

Event type	# of events in 180 days	Notes
ν_μ CC	28800	
$\overline{\nu}_\mu$ CC	2520	
ν_e CC	540	Use dE/dx to tag electron
NC	9720	
$\nu_\mu n \longrightarrow \mu^- p$ (CCQE)	4680	~50% proton containment. Will use MINOS ND for muons. Cross-section? M_A?
$\nu_\mu N \longrightarrow \nu_\mu N$ (NCE)	1420	~50% proton containment. Separating neutron and proton events? Cross-section? Δ_s?
$\nu_\mu N \longrightarrow \mu^- N \pi^+$ (CCpi+)	5490	Use dE/dx and topology to tag this channel (CCQE background)
$\nu_\mu n \longrightarrow \mu^- p \pi^0$ (CCpi0)	1850	Use dE/dx and topology to tag this channel (CCQE background)
$\nu_\mu N \longrightarrow \nu_\mu N \pi^0$ (NCpi0)	1370	Low event containment (rad length in Argon is 14 cm). Use dE/dx and topology to tag gamma

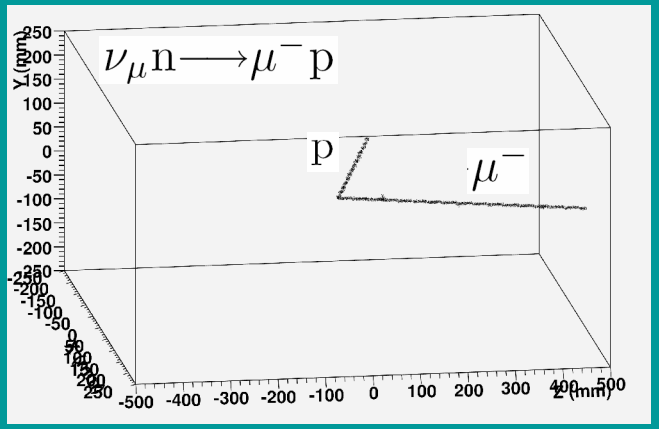
Muon angle with respect to beam axis



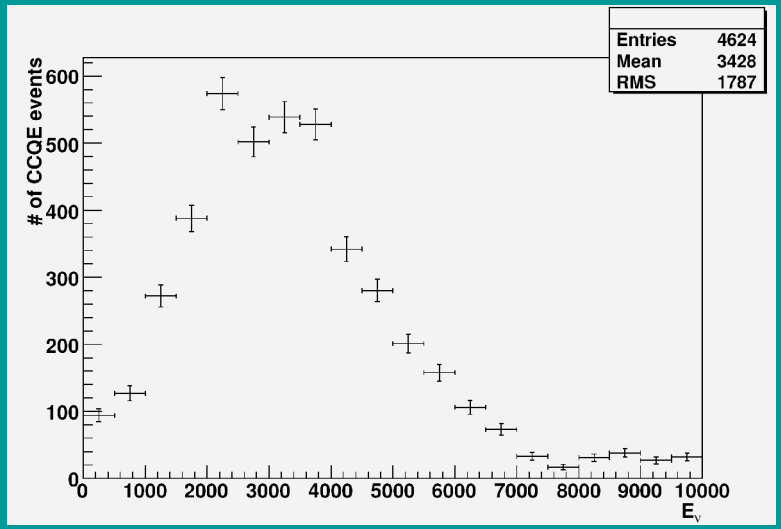


Physics?

- As a very small detector, ArgoNeuT will not be good at containing events. However, using dE/dx and LArTPC resolution, ArgoNeuT will be able to identify and separate event-types with high efficiency.
- How can we use this to our advantage?
  - CCQE events in ArgoNeuT may provide a measurement of the axial vector mass (M_A).
    - Backgrounds (CC1pi+,CC1pi0, etc.) will be tagged with high efficiency
    - We will use MINOS to catch muons and may be able to make a CCQE cross-section measurement on argon (which will help with M_A).



~4600 CCQE events in 180 days of running



  - Δ_s measurement?

$\frac{\nu p \rightarrow \nu p}{\nu n \rightarrow \nu n}$ or $\frac{\nu p \rightarrow \nu p}{\nu_\mu n \rightarrow \mu^- p}$ or $\nu p \longrightarrow \nu p$ cross section

How well can we distinguish protons from neutrons in an LArTPC?

Take home

- ArgoNeuT is an R&D-oriented LArTPC that will begin taking data in the NUMI beamline next month.
- The detector will see >45000 neutrino events in a wide variety of channels.
- Measurements of CCQE and NC-elastic cross sections on LAr are ambitious but possible.
- The LArTPC's ability to image neutrino events with high resolution and tag with high efficiency will be demonstrated.

R&D on the road to CP violation, Θ_{13}, proton decay, …